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(71) Applicant: **FLSMIDTH A/S** [DK/DK]; Vigerslev Alle 77, 2500 Valby (DK).

(72) Inventor: **CHRISTODOULOU, Lance**; 10587 South Beach Comber Way, South Jordan, Utah 84009 (US).

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(54) Title: FEEDING AND SPARGING ARRANGEMENT FOR COLUMN FLOTATION APPARATUS

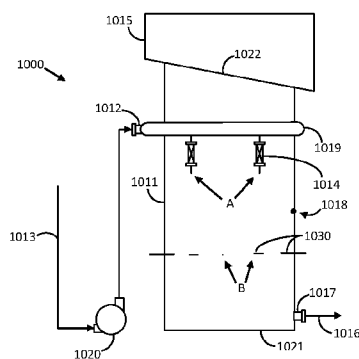


FIGURE 4

(57) Abstract: A flotation column (1000) substantially as shown and described, the flotation column (1000) having a column tank (1011) and a single upper feed inlet (1012) to supply feed slurry (1013) to the column tank (1011) via a tubular annular manifold (1019') of an upper feed distributing and sparging system (1019); the upper feed sparging system (1019) comprising a number of upper feed cavitation spargers (1014) feeding upper inlets (A) located above a vertical mid-point (1018) of the column tank (1011) with the feed slurry (1013).

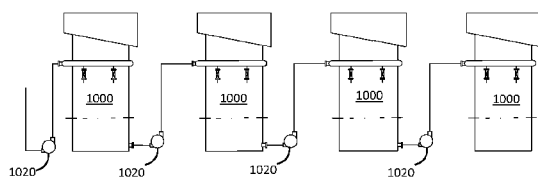


FIGURE 5



Feeding and Sparging Arrangement for Column Flotation Apparatus

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Cross-reference to Related Applications

None.

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Field of the Invention

Embodiments of the invention relate to a novel feeding and sparging arrangement for flotation columns.

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Background of the Invention

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Turning to prior art FIG. 1, a flotation column 10 traditionally employs an upper feed inlet 12 located above a column vertical midpoint 18. The vertical midpoint 18 of the flotation column 10 is located generally halfway between a surface 22 of a launder 15 and a bottom 21 of the column's tank 11. A single feed inlet 12 distributes incoming feed slurry 13 to a single circumferential point on the column tank 11. Accordingly, the single feed inlet 12 distributes the feed slurry 13 non-uniformly about the periphery of the column tank 11.

The launder 15 of the flotation column 10 is provided above the column tank 11 and receives froth containing target particles from the feed slurry 13. A lower outlet 17 removes under-flow 16 (e.g., containing gangue particles) from the column tank 11.

5 A recirculation circuit containing a second lower outlet 17', a large pump 20, a lower recycle inlet 12' located below the vertical midpoint 18, and an external dynamic sparging system 19.

10 The external dynamic sparging system 19 comprises an annular manifold 19' that surrounds the column tank 11 and is fed by the lower recycle inlet 12'. A number of cavitation spargers 14 receive material leaving the second lower outlet 17' and re-enter the column tank 11 via a number of lower inlets B. The lower recycle inlet 12' and the lower inlets B are provided below the vertical midpoint 18 of the flotation column 10. The purpose of the external dynamic sparging system 19 is to scavenge and increase residence time of particles within the column tank 11 that entered via feed inlet 12.

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Turning now, to prior art FIG. 2, a flotation column 110 may also traditionally employ a single upper feed inlet 112 located above a column vertical midpoint 118 - the vertical midpoint 118 being halfway between a surface 122 of a launder 115 and a bottom 121 of a column tank 111. The single feed inlet 112 unevenly distributes incoming feed slurry 113 to the column tank 111. This non-uniform feeding of slurry (about the periphery of the column tank 111) may reduce flotation efficiency.

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The launder 115 is provided above the column tank 111 and receives froth containing target particles from the feed slurry 113. A lower outlet 117 removes underflow 116 (e.g., containing gangue particles) from the column tank 111.

5 The embodiment shown in prior art FIG. 2 does not show a recirculation circuit as suggested in prior art FIG. 1, but instead employs a number of lower inlets B being supplied with process fluid (e.g., a process gas such as air and/or a process liquid such as water or an aqueous solution without limitation). The process fluid is delivered to the column tank 111 via a number of lower insertion spargers 130 (aka "insertion-style" spargers). Before entering the column
10 tank 111 via the single feed inlet 112, feed slurry 113 enters a cavitation tube 119, where it is spread at a first end 123 between a number of cavitation spargers 114. The sparged/aerated slurry is then reconsolidated at a second end 124 of the cavitation tube 119. The cavitation tube 119 helps prevent coalescence of pre-contacted slurry entering the flotation column.

15 Prior art FIG. 3 shows an exemplary conventional circuit or flowsheet 210 which can employ one or more large upstream distributor pumps 202. The distributor pumps supply feed slurry to a feed distributor 204 which, in turn, splits the feed slurry between a number of flotation columns 10 as shown. The flotation columns 200 shown in prior art FIG. 3 are configured in
20 parallel with respect to one another, rather than in series as will be appreciated by the inventive concepts described hereinafter.

Objects of the Invention

According to some embodiments, it is desired to provide a flotation column, flotation column flowsheet, and/or a retrofit kit for a flotation column which is configured to target fine particle recovery and promote improved kinetics and recovery, without limitation.

According to some embodiments, it is desired to provide a flotation column, flotation column flowsheet, and/or a retrofit kit for a flotation column which is configured to optimize pumping requirements, improve feed control and/or feed distribution, without limitation.

According to some embodiments, it is desired to provide a flotation column, flotation column flowsheet, and/or a retrofit kit for a flotation column which is configured to reduce and/or optimize power consumption and/or capital expenditures by eliminating the need for one or more large upstream distributor pumps 202, without limitation.

According to some embodiments, it is desired to provide a flotation column, flotation column flowsheet, and/or a retrofit kit for a flotation column which is configured to offer capital savings by eliminating the need for a feed distributor 204 while still allowing for improved distribution of feed slurry between flotation columns, without limitation.

According to some embodiments, it desired to provide a flotation column, flotation column flowsheet, and/or a retrofit kit for a flotation column which is configured to offer capital savings by enabling the use of smaller sparger pumps 1020, without limitation.

5 According to some embodiments, it desired to provide a flotation column, flotation column flowsheet, and/or a retrofit kit for a flotation column which is configured to offer improved circuit performance – for example, by increasing slurry contact and/or distributing incoming feed slurry 1013 to the column tank 1011 more uniformly about the periphery or circumference of the column tank 1011, without limitation.

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According to some embodiments, it desired to provide a flotation column, flotation column flowsheet, and/or a retrofit kit for a flotation column which may be configured to offer recovery gains approaching 4-5% more Cu recovery, when compared to prior “insertion-style” sparging alone.

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Additional goals and benefits of preferred embodiments may include, without limitation, operation at as little as 1/3 of the power than with the full external style arrangement (FIG. 1), along with as much as ~20% capital cost savings for the supply, without limitation.

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According to some embodiments, it desired to provide a flotation column circuit/flowsheet, which is configured to offer improved circuit performance and cost savings – for example, by

providing the inventive flotation column apparatus in a “series” – rather than “parallel” configuration, without limitation.

In some embodiments, it may be preferred to reduce demand for maintenance, improve the control of feed slurry introduction, improve distribution between flotation columns, and/or aid in optimized recovery performance, without limitation.

These and other objects of the present invention will be apparent from the drawings and description herein. Although every object of the invention is believed to be attained by at least one embodiment of the invention, there is not necessarily any one single embodiment of the invention that achieves all of the objects of the invention.

Brief Summary of the Invention

A flotation column (1000) has a column tank (1011) and a single upper feed inlet (1012) to supply feed slurry (1013) to the column tank (1011). The feed slurry (1013) is supplied to the column tank (1011) via a tubular annular manifold (1019') of an upper feed distributing and sparging system (1019). The upper feed sparging system (1019) comprises a number of upper feed cavitation spargers (1014) feeding upper inlets (A) which are located above a vertical midpoint (1018) of the column tank (1011). The upper feed cavitation spargers (1014) serve to promote cavitation and provide aerated feed slurry (1013) to an upper half of the column tank (1011) in a uniform fashion.

A flotation circuit may comprise a number of such flotation columns (1000). The flotation columns (1000) may be arranged in series substantially as shown and described in FIG. 5.

5 The flotation circuit may comprise a number of small pumps (1020) arranged between consecutive flotation columns (1000), without limitation.

10 A retrofit kit for producing the flotation column (1000) may comprise an upper feed sparging system (1019). The upper feed sparging system (1019) may comprise a tubular annular manifold (1019') configured to surround a column tank (1011). The upper feed sparging system (1019) may further comprise a number of upper feed cavitation spargers (1014) which are configured to extend between the column tank (1011) and the tubular annular manifold (1019').

15 The upper feed sparging system (1019) is preferably configured solely for mounting to an upper half of the column tank (1011), above a vertical midpoint (1018) of the column tank (1011).

20 A method for retrofitting a flotation column to produce a flotation column (1000) as described above and as substantially as shown in FIG. 4 may comprise one or more of the following steps. If present, a lower external dynamic sparging system (19) may be removed from a column tank (1011) and replaced with lower "insertion-style" spargers (130) operably connected to a plurality of lower inlets (B) of the column tank (1011) (e.g., for introducing

process fluids into said column tank (1011)), without limitation. If a lower external dynamic sparging system (19) or lower “insertion-style” spargers (130, 1030) are not present, a plurality of lower “insertion-style” spargers (130, 1030) may be installed, without limitation. The plurality of lower “insertion-style” spargers (130, 1030) may be operably connected to a plurality of lower inlets (B) of the column tank (1011) as shown, for introducing process fluids into said column tank (1011), without limitation. If present, a single upper feed inlet (112) located above the vertical midpoint (118) of said column tank (1011) may be optionally blocked. An upper feed distributing and sparging system (1019) may be installed. The upper feed distributing and sparging system (1019) comprises a tubular annular manifold (1019') located above a vertical midpoint (1018) of the column tank (1011).

If not already present, a plurality of upper inlets (A) may be created in the column tank (1011) to accept cavitation spargers (1014). The upper inlets (A) may be provided above a vertical midpoint (1018) of the column tank (1011), without limitation. The method may further comprise providing a plurality of upper feed cavitation spargers (1014) between the tubular annular manifold (1019') and each upper inlet (A) provided to the column tank (1011). The method may further comprise connecting the tubular annular manifold (1019') to a feed slurry (1013) via a single upper feed inlet (1012) extending from the tubular annular manifold (1019'), without limitation.

Description of the Drawings

FIGS. 1 and 2 are examples of conventional flotation columns found within the prior art.

5 FIG. 3 is an example of a prior art circuit/flowsheet comprising conventional flotation columns found within the prior art

FIG. 4 shows an exemplary non-limiting embodiment of a flotation column according to the invention.

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FIG. 5 shows an exemplary non-limiting embodiment of a flowsheet comprising a number of the novel flotation columns shown in FIG. 4.

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FIG. 6 compares features of a conventional flotation column with those of a flotation column 1000 according to embodiments of the invention (i.e., shown in FIG. 4 and FIG. 5, without limitation).

FIG. 7 shows data relating to and/or comparing an approach that places flotation columns in series.

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Detailed Description

Proposed embodiments of a flotation column 1000 may have the potential to offer similar or better recoveries as the prior art column flotation devices 10, 100 shown in FIGS. 1-3. They may also exhibit operation using as little as a third of the power consumption and/or as much as a possible 20% reduction in capital cost.

The inventive approach (FIGS. 4 and 5) differs from conventional apparatus and methods (FIGS. 1-3) because embodiments of the proposed flotation column 1000 utilize a unique feed sparging system for a flotation column 1000 which is located in the upper half of the column tank 1011. The feed sparging system has an added benefit of even, uniform circumferential distribution of feed around the column tank 1011.

The feed sparging system pre-contacts feed slurry 1013 while lower insertion lance-style insertion spargers 1030 supply supplemental process fluid (e.g., gas such as air) to the column tank 1011 via lower inlets B, in order to maintain required superficial gas velocity (J_g) requirements.

The proposed feed sparging system 1019 is entirely located in the upper half of the column tank 1011 (i.e., located above a vertical midpoint 1018 which is halfway between a surface 1022 of a launder 1015 and a bottom 1021 of the column tank 1011). The lower lance-style

insertion spargers 1030 are thus located below the vertical midpoint 1018 (i.e., within the bottom half of the column tank 1011).

The feed sparging system 1019 comprises an annular tubular manifold 1019' which receives feed slurry 1013 pumped to the annular tubular manifold 1019' via a small pump 1020 located upstream of the flotation column 1000. The annular tubular manifold 1019' delivers feed slurry 1013 to a small number of cavitation spargers 1014 which aerate the slurry 1013 and discourage coalescence. The treated (i.e., "pre-contacted") incoming feed slurry 1013 then enters the column tank 1011 via a plurality of upper inlets "A" – which are disposed circumferentially uniformly about the periphery of the column tank 1011 as shown. A lower outlet 1017 removes underflow 1016 containing gangue particles from the column tank 1011.

According to some embodiments, the cavitation spargers 1014 may have means (not shown) for introducing one or more process fluids (i.e., gas (air) and/or a liquid such as water, a reagent, or an aqueous solution) to the feed slurry 1013 therein, without limitation.

Example

Assuming a J_g of 1.75cm/s and an air fraction of 50% to the external sparger system, it may be required to operate pump 20 shown in FIG. 1 at a rate of $\sim 1,500\text{m}^3/\text{h}$, in order to adequately supply an annular manifold 19 of a conventional external sparging system, as shown in FIG. 1.

To maintain an overall J_g of 1.75 cm/s a non-limiting preferred embodiment may only require 3 to 4 six-inch external cavitation spargers 1014 to contact the feed 1013 above the vertical midpoint 1018 of the column tank 1011.

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In some preferred embodiments, greater than ten insertion-style spargers 1130 may be employed around the column tank 1011 (as shown in FIG. 4), to serve as an internal scavenging zone and/or to add supplemental air while maintaining the required superficial gas velocity. For example, greater than 15 (e.g., sixteen to eighteen) insertion-style spargers may be placed below the vertical midpoint 1018 of the column tank 1011. This starkly compares with employing nearly a dozen (e.g., 10) cavitation spargers 14 provided in the prior art arrangement FIG. 1.

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The feed rate of incoming feed slurry 13, 1013 in both cases may stay the same between traditional prior art flotation columns 10, 110 and flotation columns 1000 which are considered to be within the scope of this invention. For example, a feed rate of incoming feed slurry 13, 1013 may be, for example, 475 cubic meters per hour. However, the delivery of the feed slurry 1013 with embodiments of the present invention (FIG. 4) may be accomplished using a smaller pump 1020 (e.g., an 8 x 6 - 20 pump @ 100 horsepower); whereas prior art methods such as those depicted in FIGS. 1 and 2 might generally require a larger pump 20, 120 (e.g., a 16 x 14 - 39 pump @ 300 horsepower).

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Recovery gains anticipated by the alternate approach, may not account for potential carrying capacity constraints which could exist by reducing the feed P_{80} to flotation columns. For this, flotation column cross-sectional surface area and overall retention time, i.e. flotation column tank 1011 sizing also needs to be considered.

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Where used herein the term “feed sparging system” may be replaced with “feed distribution system” or “feed distribution and sparging system” without limitation, and this nomenclature would be readily apparent to those skilled in the art.

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It should be known that the specific features, process steps, and possible benefits shown and described herein in detail are purely exemplary in nature and should not limit the scope of the invention.

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Moreover, although the invention has been described in terms of particular embodiments and applications, one of ordinary skill in the art, in light of these teachings, can generate additional embodiments and modifications without departing from the spirit of or exceeding the scope of the claimed invention.

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Accordingly, it is to be understood that the drawings and descriptions herein are proffered

by way of example to facilitate comprehension of the invention and should not be construed to limit the scope thereof.

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Listing of Reference Numerals

A - upper inlets (above vertical midpoint of column)

B - lower inlets (below vertical midpoint of column)

5 **10, 100, 200** – conventional flotation column

11, 111, 1011 - column tank

12, 112 - single upper feed inlet to column tank (above vertical midpoint of column)

12' - lower recycle inlet (below vertical midpoint of column)

13, 113, 213, 1013 - incoming feed slurry

10 **13'** – recirculated slurry

14 - lower recirculatory cavitation spargers (below vertical midpoint of column)

15, 115, 1015 - launder (above vertical midpoint of column and above single upper feed inlet)

16, 116, 1016 - underflow (leaving column tank)

17, 117, 1017 - lower outlet (below vertical midpoint of column)

15 **17'** - second lower outlet (below vertical midpoint of column)

18, 118, 1018 - vertical midpoint of column

19 - lower external dynamic sparging system

19' – tubular annular manifold (below vertical midpoint of column)

(below vertical midpoint of column)

20 **20, 202** - large pump (e.g., a 16 x 14 - 39 pump @ 300 horsepower)

21, 121, 1021 - bottom of column tank

22, 122, 1022 - surface of launder

114 – external cavitation tube spargers

119 – external cavitation tube feeding single upper feed inlet

123 - first (upstream) end of cavitation tube

124 - second (downstream) end of cavitation tube

5 **130, 1030** – lower “insertion-style” spargers for introducing process fluids into column tank
 (e.g., for introducing a gas such as air and/or a fluid such as water)

210 – conventional circuit (flotation columns arranged in parallel)

204 – distributor

1000 – flotation column

10 **1010** – circuit (flotation columns arranged in series)

1012 - single upper feed inlet to upper feed sparging system tubular annular manifold

1014 – upper feed cavitation spargers feeding upper inlets (above vertical midpoint of column)

1019 - upper feed distributing and sparging system

15 **1019'** – tubular annular manifold (above vertical midpoint of column)

1020 – small pump (e.g., an 8 x 6 - 20 pump @ 100 horsepower)

Claims

1. A flotation column (1000) substantially as shown and described, the flotation column (1000) having a column tank (1011) and a single upper feed inlet (1012) to supply feed slurry (1013) to the column tank (1011) via a tubular annular manifold (1019') of an upper feed distributing and sparging system (1019); the upper feed sparging system (1019) comprising a number of upper feed cavitation spargers (1014) feeding upper inlets (A) located above a vertical midpoint (1018) of the column tank (1011) with the feed slurry (1013).
2. A flotation circuit comprising a number of the flotation columns (1000) described in claim 1, being arranged in series substantially as shown and described in FIG. 5.
3. The flotation circuit according to claim 2, further having a number of small pumps (1020) arranged between consecutive flotation columns (1000).
4. A retrofit kit for producing the flotation column (1000) described in claim 1, comprising an upper feed sparging system (1019), the upper feed sparging system (1019) comprising a tubular annular manifold (1019') configured to surround the column tank (1011), and a number of upper feed cavitation spargers (1014) configured to extend between the column tank (1011) and tubular annular manifold (1019'); the upper feed sparging system (1019) being configured solely for mounting to an upper half of the column tank (1011), above a vertical midpoint (1018) of the column tank (1011).

5. A method for retrofitting a flotation column to produce the flotation column (1000) as described in claim 1 and as substantially as shown in FIG. 4; the method comprising the steps of:

- i. if present, removing a lower external dynamic sparging system (19) from a column tank (1011) and replacing it with lower “insertion-style” spargers (130) operably connected to a plurality of lower inlets (B) of the column tank (1011) for introducing process fluids into said column tank (1011);
- ii. if a lower external dynamic sparging system (19) or lower “insertion-style” spargers (130, 1030) are not present, creating a plurality of lower inlets (B) in the column tank (1011), the lower inlets (B) being provided below a vertical midpoint (1018) of the column tank (1011), and, installing a plurality of lower “insertion-style” spargers (130, 1030) operably connected to the plurality of lower inlets (B) of the column tank (1011) for introducing process fluids into said column tank (1011);
- iii. if present, optionally blocking a single upper feed inlet (112) located above the vertical midpoint (118) of said column tank (1011);
- iv. If not already present, creating a plurality of upper inlets (A) in the column tank (1011), the upper inlets (A) being provided above a vertical midpoint (1018) of the column tank (1011);
- v. installing an upper feed distributing and sparging system (1019) having a tubular annular manifold (1019') located above a vertical midpoint (1018) of the column tank (1011); and

- vi. providing a plurality of upper feed cavitation spargers (1014) between the tubular annular manifold (1019') and each upper inlet (A) provided to the column tank (1011), wherein an upper feed cavitation sparger (1014) may be provided between the tubular annular manifold (1019').

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6. The method of claim 5 further comprising the step of:

- i. connecting the tubular annular manifold (1019') to a feed slurry (1013) via a single upper feed inlet (1012) extending from the tubular annular manifold (1019').

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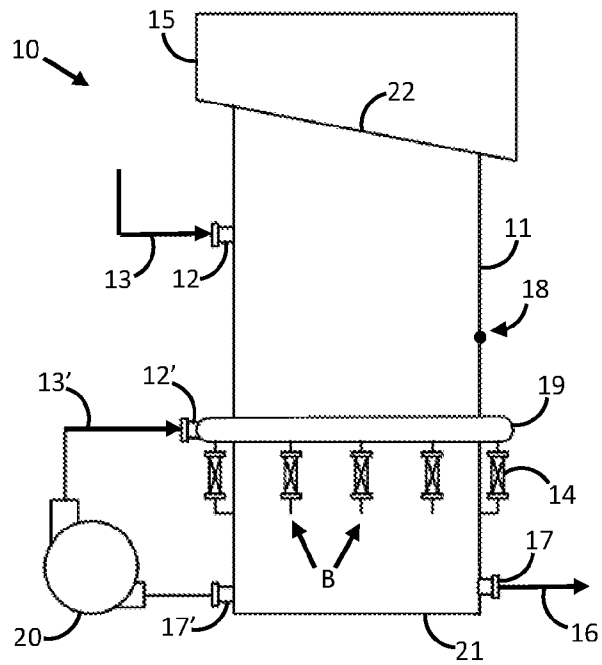


FIGURE 1
(PRIOR ART)

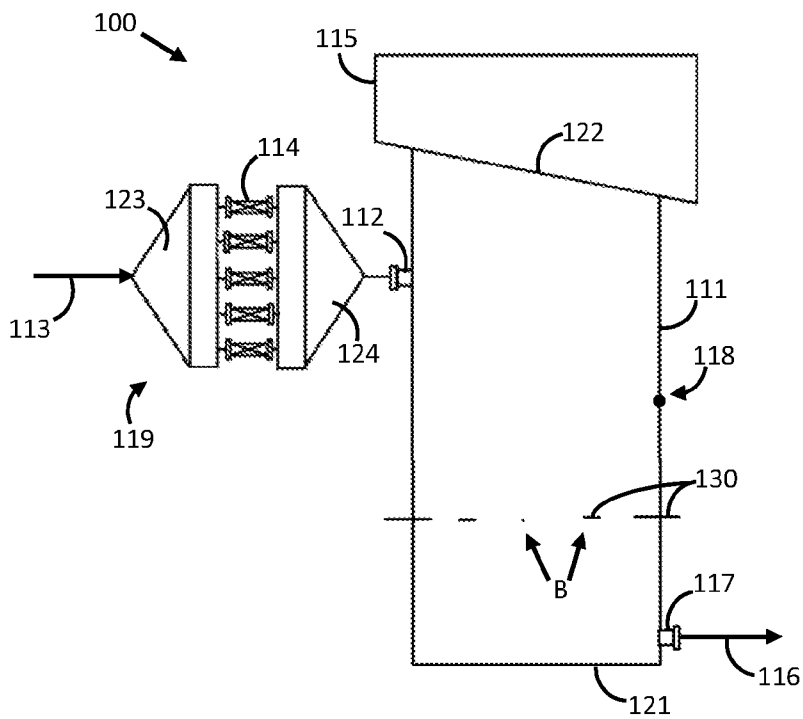


FIGURE 2
(PRIOR ART)

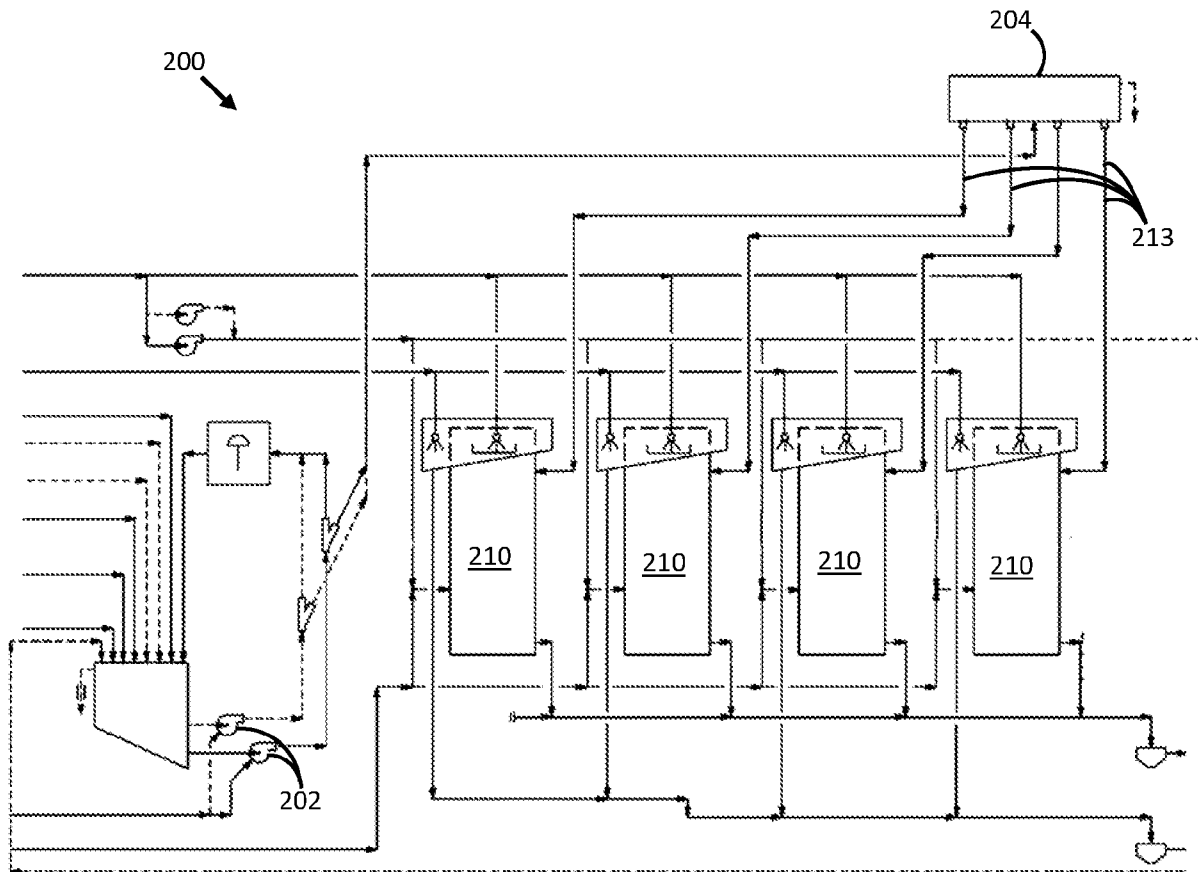


FIGURE 3
(PRIOR ART)

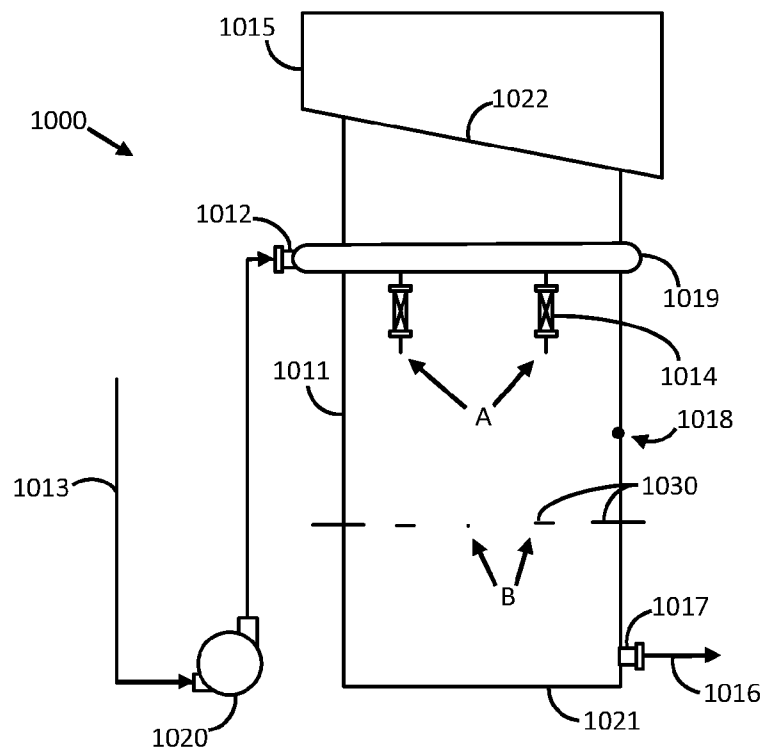


FIGURE 4

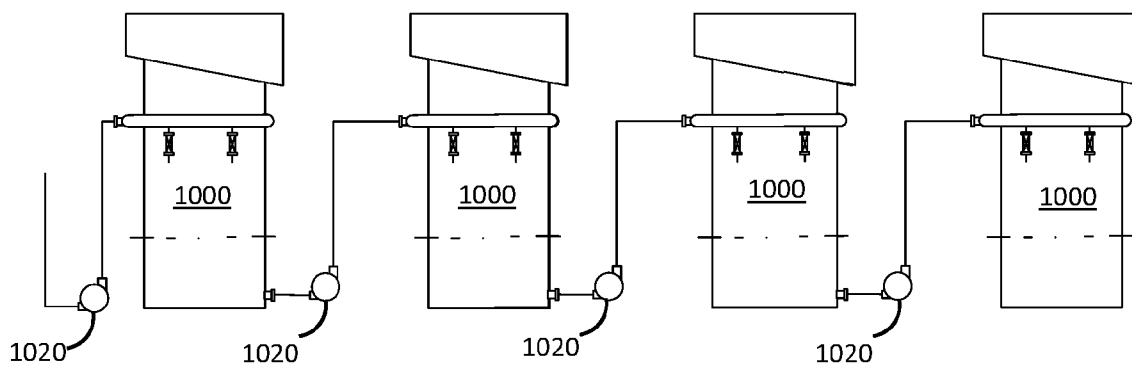


FIGURE 5

	Prior Art (Typical)	Invention
Feed Pump	> 30 x 22, 700 kW	Integral
Sparger Pump	Six (6) 16 x 14, 190 kW	Six (6) 8 x 6, 75 kW
Total Installed power	1,840 kW	450 kW
Distributor?	Yes	No

FIGURE 6

Table 5. Production statistics before and after the full cell-to-cell column reconfiguration.

	Feed Ash (%)	Clean Ash (%)	Tailing Ash (%)	Yield (%)	Recovery (%)
BEFORE					
Average	48.76	16.31	77.78	47.39	77.00
Maximum	55.11	37.38	83.25	67.95	87.10
Minimum	41.13	9.31	68.88	37.13	62.25
Std Dev	3.02	3.95	2.24	5.99	4.26
AFTER					
Average	49.72	15.26	82.37	48.82	81.85
Maximum	57.07	29.71	85.28	63.41	88.65
Minimum	42.80	9.54	78.42	34.51	71.26
Std Dev	3.13	4.46	1.23	5.56	3.48

FIGURE 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2019/059583

A. CLASSIFICATION OF SUBJECT MATTER
INV. B03D1/14 B03D1/24
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B03D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 347 128 A (BARNSCHEIDT WOLFGANG) 31 August 1982 (1982-08-31) column 4, line 66 - column 5, line 7; claim 1; figures 1, 2 -----	1-6
X	US 5 814 210 A (YOON ROE-HOAN [US] ET AL) 29 September 1998 (1998-09-29) figure 3 -----	1-6
X	AU 2012 100 021 B4 (ERIEZ MFG CO [US]) 28 May 2015 (2015-05-28) figure 1 -----	4
A	US 2016/089679 A1 (PRESTES MAURICIO ANTONIO RODRIGUES [BR]) 31 March 2016 (2016-03-31) figure 1 -----	2,3



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

27 January 2020

Date of mailing of the international search report

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European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

García Alonso, Nuria

INTERNATIONAL SEARCH REPORT

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